Informational Leaflet 71

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INTRODUCTION

This report summarizes the results of a study to determine the effects upon intertidal salmon spawning area of a causeway constructed across the tideflats of Starrigavan Creek. The causeway was part of a U.S. Forest Highway built in connection with the Sitka planned road system (Figure 1). The immediate purpose of that part of the road crossing Starrigavan Creek was to make proposed U.S. Forest Service picnic and camp ground accessible to campers arriving at the nearby State of Alaska Ferry System terminal. Road and causeway construction was started in early 1964 and finished in August of that year. The road (Project FH 11-2(2) was constructed by the Bureau of Public Roads under contract to the U.S. Forest Service.

The Alaska Department of Fish and Game was concerned with the possible effects on the fishery resource of Starrigavan Creek which might result from the installation of two 14 x 8.5 foot structured plate culverts, and the fill necessary for causeway construction. The culverts were designed to allow tidal water to flow in and out of a large tideflat area, which constitutes the intertidal area of Starrigavan Creek. The chief concern was that sediment introduced during construction of the causeway across the tideflat would be carried upstream by the incoming tidal currents and deposited in intertidal spawning areas.

Consequently to find out if sedimentation did occur, and to evaluate it's effect upon salmon production, the Department conducted measurements of egg deposition, numbers of pre-emergent fry and gravel composition.

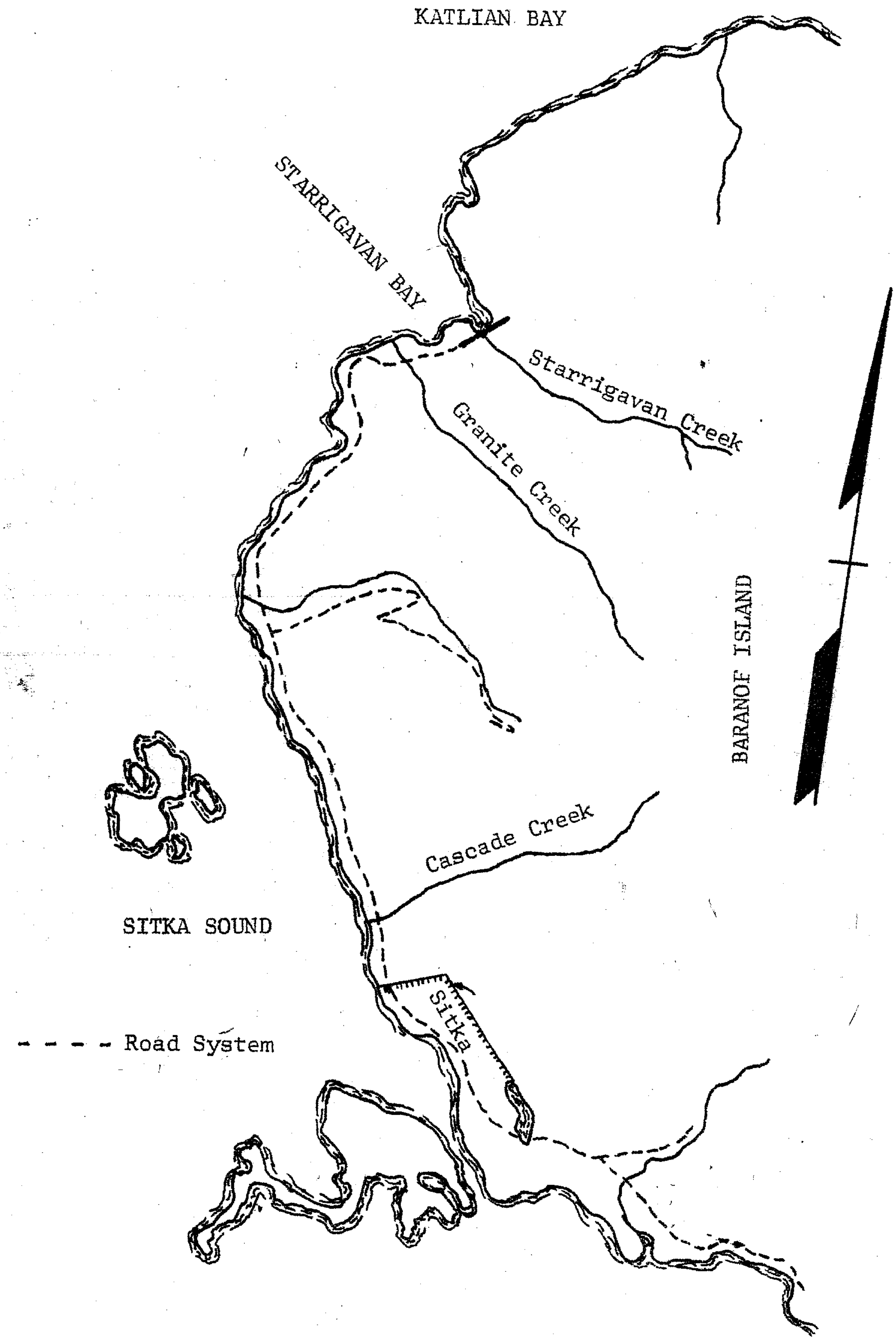

Figure 1. Location of Starrigavan Creek.

U. S. Forest Service Administration, Alaska Region, agreed verbally to assist in this study if time and money were available. They later financed the collection and analysis of the November 1964 gravel samples.

DESCRIPTION OF STARRIGAVAN CREEK

General

Starrigavan Creek runs in a southeast to northwest direction and enters Starrigavan Bay, about 6.5 miles north of the town of Sitka, Alaska (Figure 1). The watershed is approximately six square miles in area. The U.S. Bureau of Public Roads estimated the five-year return flood at 1,350 cfs. and the fifty-year return flood at 2,798 cfs. These figures indicate that the hydrologic regimen is fairly stable when compared to Indian Creek at Hollis in Kasaan Bay (Prince of Wales Island), with a drainage area about seven square miles and five year flood of 4,500 cfs. (Streamgage records for Indian Creek are on file, U.S. Forest Service Northern Forest Experimental Station, Juneau, Alaska).

Spawning Escapement

Starrigavan Creek mainly produces pink salmon (Oncorhynchus gorbuscha), some chum salmon (O. keta), and a few coho salmon (O. kisutch). Estimates of the highest number of salmon in the system at any one time[1/] during the previous five spawning seasons were as follows:

Year	Peak Count
1960	2,500
1961	4,000
1962	500
1963	12,000
1964	500

In 1963 (the only year when counts of intertidal and non-intertidal spawners were separated) we estimated that 2,000 salmon spawned in the intertidal area of concern with 10,000 fish using non-intertidal areas.

METHODS

Egg Deposition and Pre-Emergent Fry Estimates

The procedures used to estimate the egg deposition and pre-emergent fry abundance included in this report are standard methods in widespread use by fisheries agencies in Alaska.

1/ These peak counts must be considered minimal estimates of the annual runs, since fish spawning before and after this individual survey, plus unobserved fish at time of survey, are not included.

The methods and equipment used as described in the Fisheries Research Institute Field Manual, Koo (1964) and in greater detail in McNeil (1960a, 1962b).

The intertidal area of Starrigavan Creek was surveyed prior to egg deposition and pre-emergent fry sampling. This survey included only riffle areas which appeared to be suitable for spawning salmon. The upstream terminus of the survey was designated with a permanent marker and stakes were placed at each 100 foot increment downstream from this point. Each stake was marked with the linear distance from the upstream terminus, e.g. 14+00 is 1400 feet from the upstream marker 0+00. The downstream terminus of the sampling area was 20+00 (Figure 2).

Calculations of the area surveyed was the solution of a series of trapezoid area calculations. The total area for purposes of sampling was 85,640 sq. ft. This was separated into two parts, an upper area of 59,510 sq. ft. and a lower area of 26,130 sq. ft. This separation was made primarily because the lower area was disturbed by gravel removal on the north side of the stream with trucks hauling gravel passing over the streambed approximately at 15+00.

Gravel Composition

The present method of determining the amounts and sizes of streambed gravel involves separation of the material by agitation through a series of eleven Standard Tyler Screens. The content retained by each screen is measured by volumetric displacement of water and is expressed in milliliters. These measurements are then converted to percentage of total sample displacement.

The method and equipment used in this determination is described in Fisheries Research Institute Field Manual, Koo (1964) and in McNeil and Ahnell (1964), with the following differences in procedure:

1. The screens listed below were used for aggregate separation. This represents a slight change in screen opening for several screens.

76.2 mm opening	Coarse series
50.8 mm opening	Coarse series
25.4 mm opening	Coarse series
12.7 mm opening	Coarse series
6.35 mm opening	Coarse series

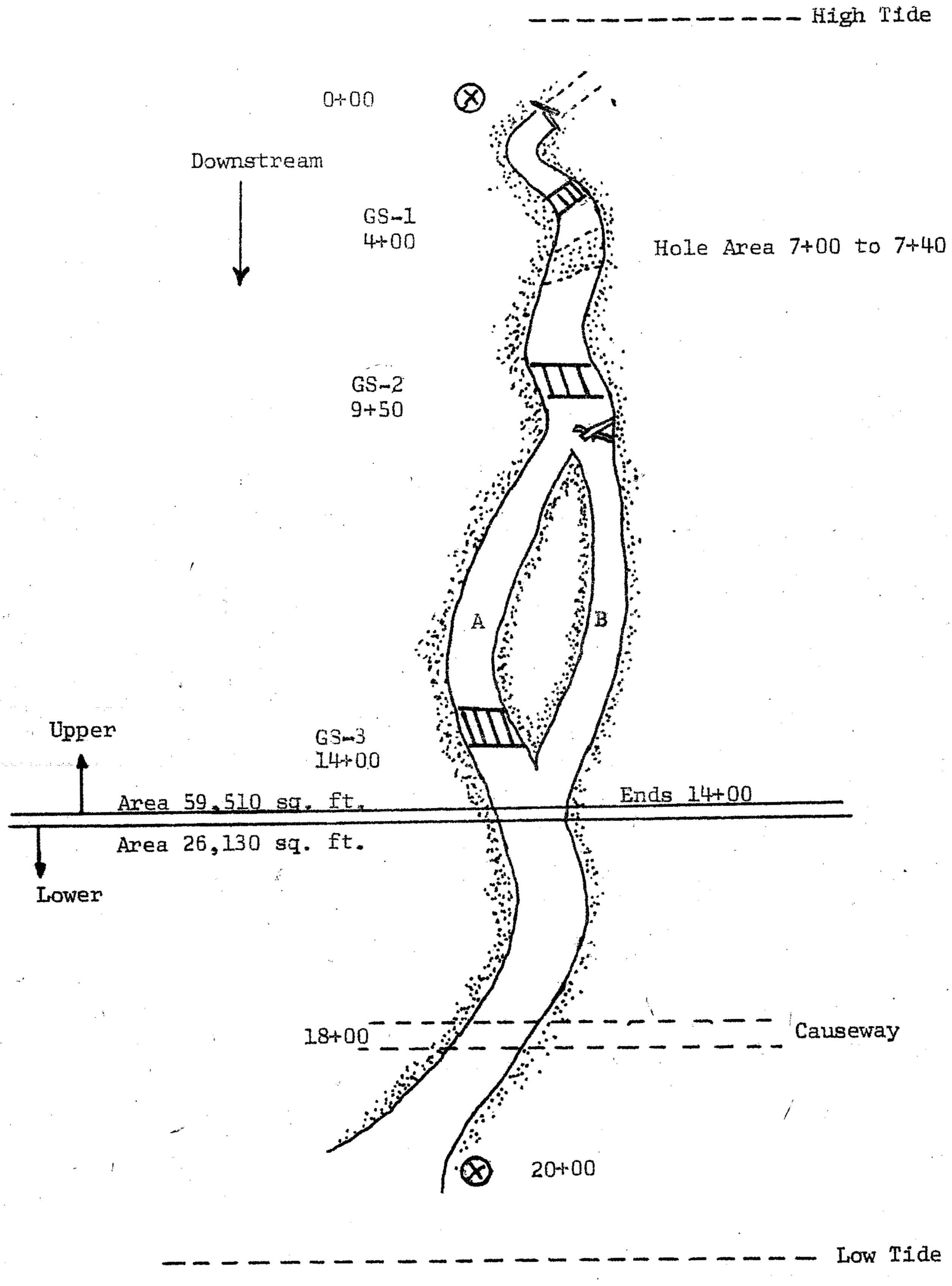

Figure 2. Intertidal Starrigavan Creek.

3.327 mm opening	US series equiv. no. 6
1.651 mm opening	US series equiv. no. 12
.833 mm opening	US series equiv. no. 20
.417 mm opening	US series equiv. no. 40
.208 mm opening	US series equiv. no. 70
.104 mm opening	US series equiv. no. 140

2. Pan silt and material retained by .208 mm and the .104 mm screens were transferred to a graduated cylinder and allowed to settle ten minutes and then volume occupied by the materials was read directly.

3. Each screen fraction was separately agitated in a water bath after the initial placement of the total sample in the screen column. The bath water and screenings were then placed on the next smaller screen size. This modification minimized the retention of the smaller size particles on the larger screens and was essentially as described in Irani and Callis (1963).

4. The core sampler was six inches in diameter and ten inches deep. Gravel samples were taken before and after causeway construction in three subareas of the Starrigavan Creek upper intertidal area in order to determine whether or not an increase in fine materials of the spawning bed had taken place. Fifteen random samples were taken from each of these areas and separated into eleven size fractions prior to construction activity, and an additional 15 samples per area were taken subsequent to construction. The analysis of the 45 pre-construction samples and the 45 post-construction samples were combined and the amounts retained by each screen size expressed as a percentage of the total volume. Figure 2 shows the approximate location of the gravel sampling areas (GS-1, -2, -3). No sampling was conducted in the lower area.

RESULTS

Egg Deposition Estimates

Figure 2 shows a sketch of the sampling area with approximate locations of the upper and lower areas and the site of causeway construction at 18+00.

Egg samples were collected on the 15th and 16th of October, 1963 in the upper and lower areas with the hydraulic sampler described by McNeil (1962a). Eggs were cleared in Stockard's solution prior to counting. Table 1 lists the density of egg deposition and reference Appendix VI shows the mathematical treatment of the data.

Table 1. Estimates of salmon egg densities in Starrigavan Creek sampling areas.

Area	Number of 2 sq. ft. samples	Total eggs	Mean number of eggs per sample	90% Confidence Limits of mean
Upper	54	2519	46.648	± 26.337
Lower	30	201	6.700	± 11.216

Egg recovery in the lower area was primarily from one point located at 15+02 with only 3 live eggs and four dead recovered in the samples taken below this point and no live eggs recovered below the proposed causeway crossing (Appendix #1).

The estimate of the number of live eggs deposited by the 1963 escapement for the upper area was 1,388,016 with 90 percent confidence limits of ± 783,657; and for the lower area the estimated deposition of live eggs was 87,536 with 90 percent confidence limits of ± 146,537 (note, the wide range of the lower area confidence limits reflects the large variance of these samples).

Some spawning activity was observed in the vicinity of the proposed causeway crossing. However, the success of the spawners in this area was expected to be negligible because the proposed causeway was estimated to be located at the two foot tide level by the U. S. Bureau of Public Roads engineers. (Bureau of Public Roads Profile for Proposed Highway Project, FM 11-2(2) specifications dated September 13, 1963).

Helle, Williamson and Bailey (1964) at Olsen Bay, Prince William Sound Alaska, found zero overwinter survival of spawn deposited below the 0 and 4 foot tide level, even though mean egg densities of 21 eggs per square foot were observed in the 3 to 4 foot tide level following spawning. Hanavan and Skud (1954) from studies on Baranof Island, Southeastern Alaska, also suggested that the area below the 4 foot tide level may be unproductive. Although the difference between the mean high and mean low water between Sitka and Cordova is approximately 8 percent, the period of inundation of the 4 foot tide level at Starrigavan based upon Sitka tides is approximately 60 percent as compared to 74 percent at Olsen Bay (estimated from U.S. Coast and Geodetic Survey, 1960).

Considering the relative lack of egg recovery in the lower area and the doubtful success of spawners in the vicinity of the causeway pre-emergent sampling was not conducted in the lower area in the spring of 1964.

Most of the eggs recovered in the upper area during sampling were above 12+00 (Appendix #II).

Pre-emergent Fry Estimate

Prior to fry emergence, the upper area of Starrigavan Creek was sampled to determine the abundance of pre-emerged salmon fry by excavating randomly with the hydraulic sampler on March 14th and 15th, 1964 at an intensity of 55 two square foot samples. Total recovery was 1,515 pink salmon fry with a mean number of 14 per square foot. No recovery of fry or dead eggs was found below 11+00. No count of egg shells present at that time was made. Table 2 lists the abundance of fry found in the upper area (reference Appendix #III).

Table 2. Estimated abundance of pre-emerged fry, spring 1964.

Area	Number of 2 sq. ft. samples	Total fry	Mean number of fry per sample	90% Confidence Limits
Upper	55	1515	27.547	± 16.063
Lower	no samples taken			

The most probable estimate of pre-emergent fry abundance produced by the 1963 escapement for the upper area was 819,615. 90 percent confidence limits were ± 476,080.

Overwinter Survival for 1963 Brood Year

The overwinter survival in the upstream area from deposition to emergence calculated from estimated abundance of live eggs present in mid-October 1963 and estimated abundance of pre-emergent fry present in mid-March 1964 was 0.590. This was relatively good survival.

Gravel Composition

Considerable evidence exists that silt is harmful to salmon (Cordone and Kelley, 1961). Probably the most significant fraction of the bottom materials in this respect is that portion passing the .833 mm screen. McNeil and Ahnell (1964) demonstrated an inverse relationship between the amount of material passing a .833 mm screen and permeability; and Wickett (1958) observed that the percentage survival is directly related to the permeability of streambed gravels.

Appendices IV and V show the gravel screenings in milliliters for each screen size in millimeters and Table 3 gives the mean percentage by volume of the

Table 3. Mean percent by volume of the fraction retained by the eleven screen sizes in mm. Settling time of ten minutes used for .208, .104 and suspended material noted as pan.

Year and Month	Area Sampled in sq. ft.	No. of Samples	76.2	50.8	25.4	12.7	6.35	3.327	1.651	.833	.417	.208	.104	Pan	Solids * Passing .833
Pre-Construction															
January 1964	10,924	43	1.33	8.64	19.63	18.02	13.49	10.22	10.13	9.15	4.84	1.88	0.74	1.92	9.38
Post-Construction															
November 1964	10,924	45	0.75	7.67	19.30	18.35	14.70	10.54	8.76	7.30	5.17	2.86	1.63	3.09	12.75

*Confidence limits for solids passing .833 mm screen.

January 1964

90%	9.38 ± 0.84
95%	9.38 ± 1.01

November 1964

90%	12.75 ± 0.92
95%	12.75 ± 1.10

fractions retained on each of the eleven screens and the fraction less than .104 which is designated as pan fraction.

Figure 3 graphs the fraction of bottom materials passing the 1.651 mm screen. The curve of the November 1964 post-construction samples is shifted to the left of the January 1964 pre-construction samples. This shift to the left indicates a higher percentage of fine materials in the post-construction gravel.

Figure 4 shows the pre-and post-construction 90 and 95 percent confidence limits of the mean percentage fines passing the 0.833 mm sieve. For both limits the post-construction samples show a higher percentage of fines.

The next step was to determine whether or not there was a change in the average composition of gravel sizes passing the 0.833 mm sieve prior and subsequent to the road construction. Statistically this reduced to a test of whether the two samples could be considered to have been drawn from populations having the same average value. A statistical test was desired which would be sensitive to differences in location between the pre- and post-construction samples but not to differences in the distribution of these samples. For this purpose the nonparametric median test was used (Mood, 1950).

The median is an order statistic and the procedure of the test is to form an ordered combined sample from the pre- and post-construction samples. If the pre-construction observations are represented as a sample $x_1, x_2, \ldots, x_{n1}$ from a distribution $f_1(x)$ and the post-construction observations as a sample $y_1, y_2, \ldots, y_{n2}$ from a distribution $f_2(y)$, the observations are arranged in a combined sequence of increasing magnitude as:

$$x_1, y_1, y_2, y_3, x_2, x_3, x_4, y_4, y_5, \ldots .$$

Let the number of x's above and below the median of the common sequence be n_{1a} and n_{1b} and the number of y's above and below the same common sample median be n_{2a} and n_{2b}. Under the null hypothesis that the two samples come from populations with the same average value, the proportion of each sample lying below the joint sample median should be the same. This can be represented as a 2X2 contingency table and the test of the distribution of the cell frequencies can be made using the chi-square distribution with one degree of freedom. Symbolically the contingency table is:

	below median	above median	totals
Pre-construction sample	n_{1b}	n_{1a}	n_1
Post-construction sample	n_{2b}	n_{2a}	n_2
Totals	$n_{1b} + n_{2b}$	$n_{1a} + n_{2a}$	$n_1 + n_2$

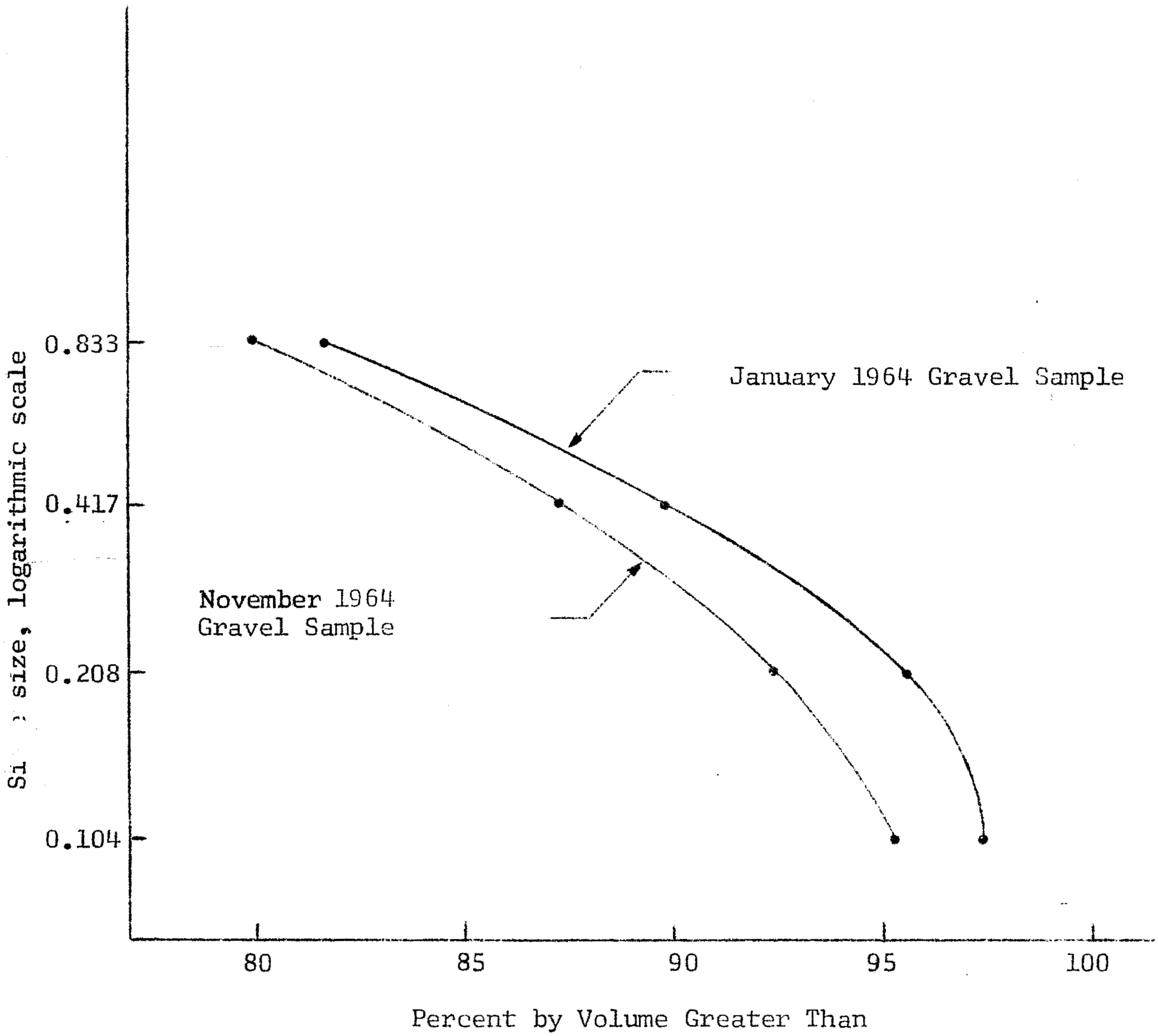

Figure 3. Fraction of bottom materials passing 1.651 mm screen.

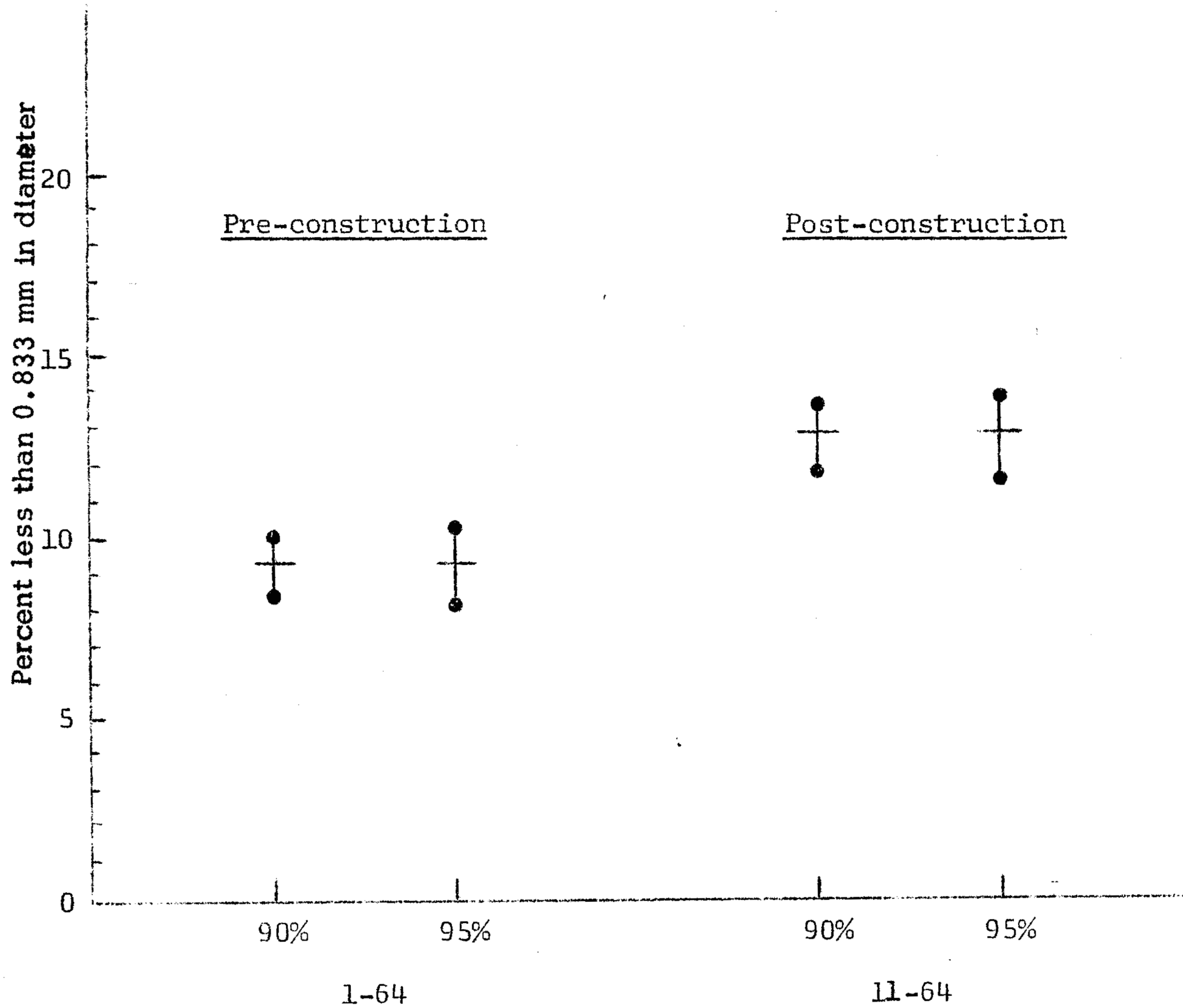

Figure 4. Starrigavan Creek - Pre & post-construction 90 & 95 percent C.L. for percent of sample $<$0.833 mm (retained on 0.417 mm).

Substituting the data given in Appendices #VII and #VIII this table becomes numerically:

	below median	above median	totals
Pre-construction sample	30	13	43
Post-construction sample	14	31	45
Totals	44	44	88

For this distribution of cell frequencies the chi-square value is:

$$X^2 = (n_1 + n_2)\left(\sum_{ij} \frac{n_{ij}^2}{n_i . n_j} - 1 \right) = 13.112$$

The probability of a chi-square value this large is less than 0.001. This is a very unlikely distribution of cell frequencies, therefore, the null hypothesis that the location of the samples is the same is rejected and one would conclude there is a significant change in the average composition of gravel sizes passing a 0.833 mm sieve prior and subsequent to the road construction. Figures 3 and 4 show that this change is in the direction of increased fines in the stream bed gravel. (See Appendix VII and VIII).

CONCLUSIONS

1. Egg deposition sampling conducted in the fall of 1963 with the recovery of only 2 dead eggs from the 28 square feet excavated in the vicinity of or downstream from the causeway indicated no spawner success. This observation concurred with observations of other workers Helle, Williamson, and Bailey (1964) on mortality of salmon spawn deposited at this level in the intertidal zone.

2. Estimated production of 14 fry per square foot in the intertidal area upstream from the causeway, in the spring of 1964 indicated that this area is the one where most salmon are produced.

3. The comparison of gravel composition analyses between samples taken in January of 1964 (pre-construction), and those taken in November 1964 (post-construction), showed that an increase of approximately 4 percent in particles less than .833 mm in diameter occurred during this period. This increase could have been caused by construction of the causeway.

RECOMMENDATIONS

Although the concentration of sediment in spawning gravels that can be tolerated by developing salmon embryos is not yet known, a rise of 4 percent would definitely decrease permeability (hence possibly survival) of these gravels (McNeil and Ahnell, 1964). Therefore the following recommendations are suggested:

1. That the same sampling areas be again sampled in the fall of 1966 and results of the 1966 sampling be compared with the results of the two previous samplings.

2. If results of the 1966 sampling show that the amount of fine materials in the streambed is still higher than the pre-construction level, then this stream would be placed on the list of streams to be cleaned with the "Riffle Sifter", being developed by the Forest Service. In the event that this device is not available some other means of fines removal should be considered.

ACKNOWLEDGEMENTS

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APPENDIX #I. STARRIGAVAN CREEK DEPOSITION ESTIMATE, 15-16 OCTOBER 1963, LOWER SAMPLING AREA (26,130 sq. ft.)

Point	Location Between	Recovery per 2 square foot sample Live Eggs	Dead Eggs	Shells
1	15+02	198	254	63
2	15-16+00	0	1	0
3	"	0	0	0
4	"	0	0	1
5	"	0	1	0
6	'	0	0	0
7	16-17+00	0	0	0
8	"	0	0	0
9	"	0	3	3
10	"	3	0	0
11	"	0	1	0
12	17-18+00	0	0	0
13	"	0	1	0
14	"	0	0	0
15	"	0	0	0
16	"	0	0	0
17	"	0	1	0
18	18-19+00	0	0	0
19	"	0	0	0
20	18-19+00	0	0	0
21	19-20+00	0	0	0
22	"	0	0	0
23	"	0	0	0
24	"	0	0	0
25	"	0	0	0
26	"	0	0	0
27	"	0	1	0
28	"	0	0	0
29	"	0	0	0
30	19-20+00	0	0	0

NOTE: Causeway crosses stream at 18+00.

APPENDIX #II. STARRIGAVAN CREEK DEPOSITION ESTIMATE, 15-16 OCTOBER 1963, UPPER SAMPLING AREA (59,510 sq. ft.)

Point	Location Between	Recovery per 2 square foot sample: Live Eggs	Dead Eggs	Shells
1	0-1+00	0	0	0
2	"	192	4	10
3	"	53	1	2
4	"	50	7	1
5	1-2+00	0	0	0
6	"	1	0	0
7	"	37	11	9
8	3-4+00	23	2	0
9	"	0	0	0
10	"	48	2	2
11	"	16	2	1
12	4-5+00	136	5	10
13	"	83	2	7
14	"	0	0	0
15	"	5	11	4
16	7+40-8+00	0	0	0
17	"	0	1	0
18	8-9+00	0	0	0
19	"	35	2	9
20	"	0	0	0
21	"	1	0	0
22	9-10+00	283	3	4
23	"	1	2	2
24	"	90	113	4
25	"	238	7	7
26	"	734	4	30
27	"	0	0	0
28	"	25	2	0
29	"	0	0	0
30	10-11+00	1	5	0
31	"	229	0	5
32	"	63	5	5
33	"	30	9	0
34	"	19	5	1
35	"	5	2	0
36	"	0	0	0
37	"	58	1	2
38	"	45	0	0
39	11-12+00	15	68	2
40	12-13+00	0	0	0
41	13-14+00	0	0	0
42	"	1	1	1
43	"	0	0	0
44	"	1	0	0
45	13-14+00	1	0	0

APPENDIX # II: STARRIGAVAN CREEK DEPOSITION ESTIMATE, 15-16 OCTOBER 1963, UPPER SAMPLING AREA (59,510 sq. ft.) (Continued)

Point	Location Between	Recovery per 2 square foot sample Live Eggs	Dead Eggs	Shells
46	14-15+00	0	0	0
47	"	0	0	0
48	"	0	0	0
49B	12-15+00	0	0	0
50B	"	0	0	0
51B	"	0	0	0
52B	"	0	0	0
53B	"	0	0	0
54B	"	0	0	0

NOTE: Samples designated B taken in side channel.

APPENDIX #III. STARRIGAVAN CREEK PRE-EMERGENT FRY ESTIMATE, 14-15 MARCH, 1964, UPPER SAMPLING AREA (59,510 sq. ft.)

Point	Location Between	Recovery per 2 square foot sample Live Fry	Dead Fry	Live Eggs	Dead Eggs
1	1+50	91 P	0	0	0
2	"	74 P	0	0	0
3	"	10 P	0	0	0
4	"	0	0	0	0
5	"	41 P	0	0	0
1	2+00	2 P	0	0	0
2	"	0	0	0	0
3	"	0	0	0	30
4	"	0	0	0	65
5	"	0	0	0	0
1	2+50	0	0	0	0
2	"	0	0	0	0
3	"	0	0	0	0
4	"	0	0	0	0
5	"	107 P	0	0	0
1	3+00	33 P	0	0	30
2	"	0	0	0	0
3	"	120 P	0	0	0
4	"	0	0	0	0
5	"	397 P	0	0	0
1	4+00	95 P	0	0	0
2	"	79 P	0	0	0
3	"	0	0	0	0
4	"	0	0	0	0
5	"	1 P	0	0	0
1	5+00	130 P	0	0	0
2	"	20 P	0	0	0
3	"	19 P	0	0	0
4	"	289 P	0	0	0
5	"	5 P	0	0	0
1	8+50	0	0	0	0
2	"	0	0	0	0
3	"	0	0	0	0
4	"	0	0	0	5
5	"	0	0	0	0
1	9+00	2 P	0	0	5
2	"	0	0	0	0
3	"	0	0	0	0
4	"	0	0	0	100
5	"	0	0	0	0
1	10+00	0	0	0	0
2	"	0	0	0	100
3	"	0	0	0	0
4	"	0	0	0	0
5	"	0	0	0	0

APPENDIX #III. STARRIGAVAN CREEK PRE-EMERGENT FRY ESTIMATE, 14-15 MARCH, 1964, UPPER SAMPLING AREA (59,510 sq. ft.) (Continued)

Point	Location Between	Recovery per 2 square foot sample Live Fry	Dead Fry	Live Eggs	Dead Eggs
1	11+00	0	0	0	0
2	"	0	0	0	0
3	"	0	0	0	0
4	"	0	0	0	0
5	"	0	0	0	0
1	13+60	0	0	0	0
2	"	0	0	0	0
3	"	0	0	0	0
4	"	0	0	0	0
5	"	0	0	0	0

P = pinks

APPENDIX #IV. STARRIGAVAN CREEK GRAVEL SAMPLING - - JANUARY 1964

Screenings in milliliters retained on these sizes in mm.
Total sample area - 10,924 sq. ft.

AREA: Section I, II, III

No.	76.2	50.8	25.4	12.7	6.35	3.327	1.651	.833	.417	.208	.104	Pan
1	8	202	642	655	440	259	291	149	78	41	8	25
2	0	455	415	343	313	221	230	132	--	27	6	35
3	0	790	315	390	315	292	280	435	155	48	8	27
4	0	0	540	618	494	460	310	456	296	129	27	64
5	0	350	446	311	322	233	317	630	460	75	11	16
6	0	320	475	294	298	275	334	429	135	34	10	21
7	0	620	505	741	393	381	330	180	52	36	23	50
8	0	156	410	572	484	370	340	350	176	74	16	49
9	0	0	531	643	538	423	345	223	120	94	64	166
10	0	592	485	345	255	198	232	207	90	29	8	15
11	0	277	624	387	345	246	258	236	127	30	12	36
12	0	623	350	541	430	320	404	282	145	70	61	111
13	0	0	577	881	435	283	223	134	89	57	23	84
14	0	158	548	505	315	216	239	105	59	53	16	36
15	0	119	840	308	637	339	280	180	120	42	16	50
16	0	400	435	486	383	350	250	175	119	80	18	80
	0	140	491	534	373	315	278	240	140	93	30	35
18	0	0	185	718	467	260	216	118	138	60	201	60
19	0	0	735	306	244	253	182	98	43	36	10	35
20	0	308	586	330	146	199	108	84 combined		28	6	4
21	0	275	405	350	270	226	271	193	64	44	7	35
22	0	0	586	492	290	205	225	146	72	24	8	115
23	0	231	450	317	215	145	138	225	110	28	5	40
24	0	513	383	306	282	248	300	252	105	26	8	85
25	0	182	460	440	280	250	311	298	190	43	13	115
26	356	180	632	445	330	224	205	127	92	20	6	65
27	0	340	475	355	240	230	296	350	171	54	9	25
28	0	120	828	593	370	191	142	128	76	36	9	20
29	0	104	647	461	263	216	215	175	128	71	20	45
30	0	267	400	554	395	319	350	220	117	72	18	72
31	0	190	248	417	300	244	310	283	96	26	8	25
32	0	136	220	354	335	255	297	323	135	28	7	27
33	0	0	510	360	304	248	265	252	142	30	6	25
34	0	283	646	541	339	199	154	118	72	13	5	35
35	0	194	455	342	255	195	264	365	142	41	9	32
36	771	108	492	343	260	112	90	47	39	42	17	30
37	0	78	796	502	465	346	255	195	127	98	29	110
38	0	304	566	629	465	326	305	287	145	34	9	35
39	0	0	550	487	319	247	310	445	250	36	5	75
40	0	0	896	794	517	305	204	217	174	85	24	85
41	0	265	407	440	353	263	210	144	122	81	23	50
	0	293	486	556	390	377	393	379	159	40	10	30
43	343	244	538	470	365	319	307	239	149	46	12	15
44	0	454	425	460	376	308	325	200	74	43	11	45
45	0	547	543	414	381	315	345	299	127	38	9	17

APPENDIX #IV. STARRIGAVAN CREEK GRAVEL SAMPLING - - JANUARY 1964
(Continued)

AREA: Section I

o.	76.2	50.8	25.4	12.7	6.35	3.327	1.651	.833	.417	.208	.104	Pan
3	0	156	410	572	484	370	340	350	176	74	16	49
.2	0	623	350	541	430	320	404	282	145	70	61	111
8	0	0	185	718	467	260	216	118	138	60	201	60
3	343	244	538	470	365	319	307	239	149	46	12	15

AREA: Section II

7	0	140	491	534	373	315	278	240	140	93	30	35
0	0	308	586	330	146	199	108	combined	84	28	6	4
4	0	513	383	306	282	248	300	252	105	26	8	85
7	0	340	475	355	240	230	296	350	171	54	9	25
.8	0	120	828	593	370	191	142	128	76	36	9	20
9	0	104	647	461	263	216	215	175	128	71	20	45
	0	267	400	554	395	319	350	220	117	72	18	72

AREA: Section III

2	0	455	415	343	313	221	230	132	---	27	6	35
6	0	320	475	294	298	275	334	429	135	34	10	21
.0	0	592	485	345	255	198	232	207	90	29	8	15
1	0	277	624	387	345	246	258	236	127	30	12	36
9	0	0	735	306	244	253	182	98	43	36	10	35
1	0	275	405	350	270	226	271	193	64	44	7	35
2	0	0	586	492	290	205	225	146	72	24	8	115
5	0	182	460	440	280	250	311	298	190	43	13	115
3	0	0	510	360	304	248	265	252	142	30	6	25
4	0	283	646	541	339	199	154	118	72	13	5	35
5	0	194	455	342	255	195	264	365	142	41	9	32

NOTE: Because of label loss not all samples are separated into sub-sample area.

APPENDIX V. STARRIGAVAN CREEK GRAVEL SAMPLING - NOVEMBER 1964

Screenings in milliliters retained on these sizes in mm.
Total sample area - 10,924 sq. ft.

AREA: Section I

No.	76.2	50.8	25.4	12.7	6.35	3.327	1.651	.833	.417	.208	.104	Pan
1	0	0	255	425	520	450	325	195	145	175	30	103
2	0	255	520	675	500	525	275	180	130	170	90	68
3	0	285	470	545	510	295	185	155	85	70	45	44
4	0	365	695	650	450	305	165	150	105	115	80	152
5	0	0	440	700	565	375	250	170	185	140	55	77
6	0	0	645	660	525	365	295	250	200	90	80	116
7	0	0	620	600	530	290	295	200	195	180	80	173
8	0	0	490	575	530	395	250	190	125	205	170	146
9	0	0	485	725	470	275	150	90	80	50	40	87
10	0	198	555	736	699	460	426	300	210	137	37	31
11	0	0	600	600	445	305	225	130	90	60	45	80
12	0	333	481	460	346	365	320	311	207	161	23	111
13	0	270	470	525	340	245	205	175	145	70	15	22
14	0	240	275	489	520	436	391	157	125	65	17	115
15	0	220	405	470	420	280	220	170	130	115	40	90

AREA: Section II

No.	76.2	50.8	25.4	12.7	6.35	3.327	1.651	.833	.417	.208	.104	Pan
1	0	70	470	565	500	375	450	480	265	80	30	114
2	0	210	700	700	495	315	270	250	140	75	30	58
3	0	355	640	550	545	330	170	115	80	60	105	72
4	0	215	500	620	455	375	285	195	125	60	55	92
5	0	555	310	400	470	315	240	165	100	60	40	72
6	470	295	350	370	375	270	235	255	160	55	25	46
7	0	225	600	300	410	240	205	175	130	65	30	50
8	0	335	480	625	380	260	225	190	150	80	65	120
9	0	295	625	595	425	280	235	265	165	60	30	88
10	0	0	880	540	405	250	185	160	130	125	70	112
11	0	485	610	490	380	220	165	110	145	170	75	192
12	0	0	725	430	470	410	375	260	175	50	25	86
13	0	560	620	595	295	130	62	10	23	35	105	60
14	0	0	530	665	370	275	295	385	185	115	60	160
15	0	355	710	600	375	350	350	280	230	100	43	190

AREA: Section III

No.	76.2	50.8	25.4	12.7	6.35	3.327	1.651	.833	.417	.208	.104	Pan
1	0	0	960	654	531	440	425	203	133	52	21	100
2	0	325	675	500	425	335	345	300	250	80	40	100
3	0	440	510	390	410	325	370	375	140	50	30	71
4	230	225	825	425	375	240	235	270	100	40	9	73
[illegible]	0	370	740	375	350	250	285	325	175	50	20	52
[illegible]	0	255	775	610	355	245	250	195	115	40	15	32
7	0	310	576	485	384	310	332	325	213	66	19	25

APPENDIX V. STARRIGAVAN CREEK GRAVEL SAMPLING - NOVEMBER 1964 (Continued)

AREA: Section III

No.	76.2	50.8	25.4	12.7	6.35	3.327	1.651	.833	.417	.208	.104	Pan
8	0	425	705	695	355	230	200	200	175	40	25	38
9	315	210	635	425	375	250	270	275	175	68	25	150
10	0	218	700	540	484	453	350	365	375	95	23	129
11	0	0	629	700	562	498	412	317	262	121	66	216
12	0	553	790	496	338	238	240	190	276	62	17	21
13	0	717	460	672	520	368	329	246	205	90	30	114
14	0	61	493	755	490	420	350	478	247	58	24	137
15	0	250	910	620	495	230	100	70	70	45	45	120

APPENDIX VI. FORMULAS USED FOR STATISTICAL COMPUTATIONS

EGG DEPOSITION

Notation

Aj : total area of study area j.

aj : total area sampled in study area j.

n_{Ej} : number of egg deposition samples taken in study area j.

E_{ij} : number of eggs recovered in sample i of study area j.

$\overline{E}_{\cdot j}$: mean number of eggs per sample for study area j.

$\hat{E}_{\cdot j}$: total estimated number of eggs in study area j.

s^2_{Ej} : sample variance for egg deposition in study area j.

u : area of sampling frame, equal to 2 square feet.

j : upper and lower sampling areas

$j = 1$ for upper sample area

$j = 2$ for lower sample area

$t_{1-\alpha/2}$: t-statistic at the α level of significance.

S : overwinter survival from egg to pre-emergent fry stage.

FORMULAS:

$$aj = u\, n_{Ej}$$

$$\overline{E}_{\cdot j} = \frac{\sum_i E_{ij}}{n_{Ej}}$$

$$\hat{E}_{\cdot j} = \frac{Aj}{u}\,\overline{E}_{\cdot j} = \frac{Aj}{aj}\sum_j E_{ij}$$

$$s^2_{Ej} = \frac{1}{n_{Ej}(n_{Ej} - 1)}\left[n_{Ej}\sum_i E^2_{ij} - \left(\sum_i E_{ij}\right)^2 \right]$$

90 percent confidence interval for the mean:

$$\bar{E}_{\bullet j} \pm \frac{t_{1-\alpha/2}\, s_{Ej}}{\sqrt{n_{Ej}}}$$

Overwinter survival

COMPUTATIONS:

upper sampling area:

$$\bar{E}_{\bullet 1} = \frac{2,519}{54} = 46.648 \text{ eggs/sample}$$

$$\hat{E}_{\bullet 1} = \frac{(59,510)}{(2)\ (54)}\ (2,519) = 1,388,016 \text{ eggs}$$

$$s^2_{E1} = \frac{1}{(54)\ (53)} \left[(54)\ (820,797) - (2,519)^2 \right] = 13,269.629$$

$$s_{E1} = \sqrt{13,269.629} = 115.194$$

90 percent confidence interval for $\bar{E}_{\bullet 1}$:

$$46.648 \pm \frac{(1.68)\ (115.194)}{7.348}$$

$$46.648 \pm 26.337$$

lower sampling area:

$$\bar{E}_{\bullet 2} = \frac{201}{30} = 6.700 \text{ eggs/sample}$$

$$\hat{E}_{\bullet 2} = \frac{26,130}{(2)\ (30)}\ (201) = 87,536 \text{ eggs}$$

$$s^2_{E2} = \frac{1}{(30)\ (29)} \left[(30)(39,213) - (201)^2 \right] = 1,305.734$$

$$s_{E2} = \sqrt{1,305.734} = 36.135$$

confidence interval for $\overline{E}_{\cdot 2}$:

$$6.700 \pm \frac{(1.70)(36.135)}{5.477}$$

$$6.700 \pm 11.216$$

PRE-EMERGENT FRY

Notation:

A : total area of upper study area.

a : total area sampled in upper study area.

n_F : number of pre-emergent fry samples taken in upper study area.

F_i : number of pre-emergent fry recovered in sample i of upper study area.

$\overline{F}$: mean number of pre-emergent fry per sample for upper study area.

$\hat{F}$: total estimated number of pre-emergent fry in upper study area.

s_F^2 : sample variance for pre-emergent fry in upper study area.

u : area of sampling frame, equal to 2 square feet.

$t_{1-\alpha/2}$: t-statistic at the α level of significance.

FORMULAS:

$$a = u\, n_F$$

$$\overline{F} = \frac{\sum_i F_i}{n_F}$$

$$\hat{F} = \frac{A}{u}\, \overline{F} = \frac{A}{a} \sum_i F_i$$

$$s_F^2 = \frac{1}{n_F\,(n_F - 1)} \left[n_F \sum_i F_i^2 - \left(\sum_i F_i\right)^2 \right]$$

90 percent confidence interval for the mean:

$$\bar{F} \pm \frac{t_{1-\alpha/2}\ s_F}{\sqrt{n_F}}$$

COMPUTATIONS:

$$\bar{F} = \frac{1515}{55} = 27.547 \text{ fry/sample}$$

$$\hat{F} = \frac{(59,510)}{(2)\ (55)}\ (1,515) = 819,615 \text{ fry}$$

$$s_F^2 = \frac{1}{(55)(54)} \left[(55)(316,567) - (1,515)^2 \right] = 5,089.549$$

$$s_F = \sqrt{5,089.549} = 71.341$$

90 percent confidence interval for $\bar{F}$:

$$27.547 \pm \frac{(1.67)(71.341)}{7.417}$$

$$27.547 \pm 16.063$$

Overwinter survival

formula & computation:

$$S = \frac{\sum_i F_i}{\sum_i E_{i1}} = \frac{819,615}{1,388,016} = 0.590$$

APPENDIX VII. CUMULATIVE PERCENTAGE OF FINES PASSING THROUGH THE 0.833 mm SIEVE FOR THE JANUARY 1964 SAMPLES.

Sample Number	Percent Passing 0.833 Sieve	Sample Number	Percent Passing 0.833 Sieve
1	5.4	26	5.6
2	7.8	27	11.3
3	15.2	28	10.0
4	17.7	29	7.2
5	7.6	30	9.3
6	4.9	31	9.5
7	10.5	32	5.2
8	14.1	33	9.8
9	5.8	34	5.5
10	8.0	35	12.1
11	11.6	36	7.2
12	9.1	37	13.4
13	7.3	38	11.1
14	7.8	39	11.7
15	10.7	40	7.7
16	11.2	41	7.3
17	19.0	42	6.4
18	6.4	43	6.3
19	7.0		
20	10.1		
21	9.6		
22	8.9		
23	14.0		
24	6.8		
25	10.2		

APPENDIX VIII. CUMULATIVE PERCENTAGE OF FINES PASSING THROUGH THE 0.833 mm SIEVE FOR THE NOVEMBER 1964 SAMPLES

Sample Number	Percent Passing 0.833 Sieve	Sample Number	Percent Passing 0.833 Sieve
1	16.3	24	11.2
2	13.5	25	15.3
3	9.1	26	19.1
4	13.6	27	11.2
5	15.5	28	8.9
6	15.1	29	17.1
7	19.9	30	15.7
8	21.0	31	8.7
9	10.5	32	13.9
10	11.0	33	9.4
11	10.7	34	7.3
12	22.7	35	9.9
13	10.2	36	7.0
14	11.4	37	10.6
15	14.6	38	9.0
16	14.4	39	13.2
17	9.4	40	16.7
18	10.5	41	17.6
19	11.2	42	11.7
20	10.0	43	11.7
21	9.8	44	13.3
22	11.3	45	9.5
23	14.3		